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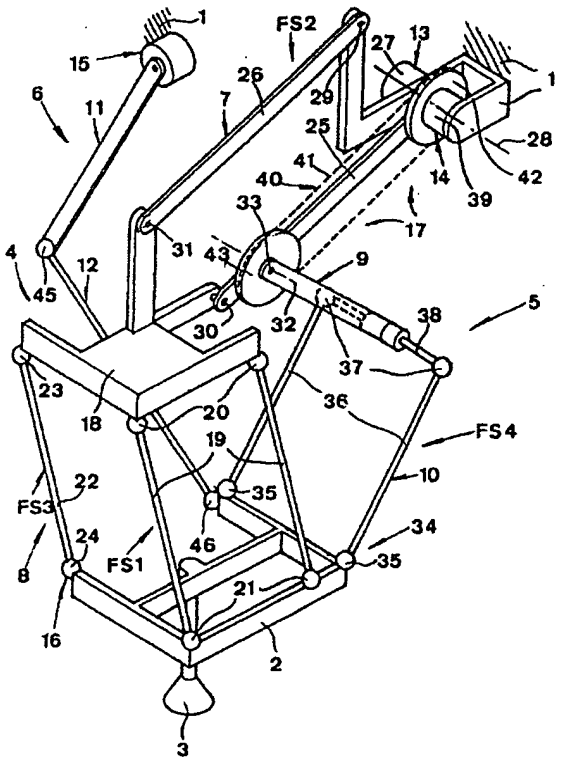
(57) Abstract

A robot for movement of a moveable element (2) relative to a base element (1) comprises at least two link devices (4, 5, 6) coupleed between the elements. These link devices comprise each at least two mutually articulated link units (7, 8; 9, 10; 11, 12) and power exerting arrangements (13, 14, 15) adapted to pivot the link devices for changing the relative position of the elements. A first (4) of the link devices is connected with the moveable element (2) via a hinge connection (16) so that there are, on consideration of the robot in its entirety, at least two degrees of freedom in the form of relative pivotability about two pivot axes, real or imaginary, extending at an angle relative to each other between the first link device (4) and said element (2). A further (5) of the link devices is connected to the base element (1) via a hinge connection (32, 33, 28) which on consideration of the robot in its entirety provide for freedom of movement between the further link device (5) and the base element (1) with respect to at least two degrees of freedom consisting of pivotability about two different pivot axes, real or imaginary.



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A device for relative movement of two elements

FIELD OF THE INVENTION

This invention is related to a device for relative movement of two elements, one of which forms a base element whereas a second is moveable relative to the base element, comprising at least two link devices coupled between the elements, said link devices each comprising at least two mutually articulated link units, and power exerting arrangements adapted to cause the link devices to pivot for changing the relative position of the elements, a first of the link devices being connected to one of the elements via a hinge connection so that there are, on consideration of the device in its entirety, at least two degrees of freedom between said first link device and said element in the form of relative pivotability about two pivot axes, real or imaginary, placed at an angle relative to each other.

The relative movement of the two elements has the purpose to position them mutually in a manner aimed at by means of the power exerting arrangements. More specifically, the device according to the invention is intended to form a manipulator or robot. The moveable of the elements is intended to carry, directly or indirectly via a carrying arrangement, a working member to execute the function aimed at.

PRIOR ART

A robot according to the precharacterising part of the enclosed claim 1 is described in US patent 4 976 582. For the positioning

of the second element, the known robot comprises three power exerting arrangements, which comprise three power exerting members arranged in a triangular distribution on the first element. Each of the power members is connected to the moveable second element via its own connection comprising a link device each comprising at least two mutually articulated link units. First link units hingedly connected to the first element comprise one single degree of freedom of movement relative to the first element. The second link units on the other hand are connected to the first link unit and to the second element respectively via connections providing, on consideration of the device in its entirety, two degrees of freedom.

A disadvantage with this known type of robot is that it becomes comparatively bulky as a consequence of the triangular distribution discussed herein above. Furthermore, it is structurally difficult to design the known robot with the required flexibility concerning working area and movement area since the first link units project in a star shaped manner from the first element.

OBJECT OF THE INVENTION

The invention primarily aims at devising routes to develop the device of the kind defined by way of introduction so as to eliminate or at least reduce one or more of the disadvantages mentioned herein above, a particular aim being to provide a great flexibility as to the design of the device and an optimum of working area for the device. It is secondarily aimed at to devise routes to realise, in a rational and uncomplicated manner, transmission of movements from the base element to the moveable element.

SUMMARY OF THE INVENTION

As far as the primary aspect of the invention is concerned, the object presented is achieved by a further of the link devices be-

ing connected to another of the elements via a hinge connection which, on consideration of the device in its entirety, provide for freedom of movement between said further link device and said another of the elements in respect of at least two degrees of freedom consisting of pivotability about two different pivot axes, real or imaginary.

In this way conditions are created for a more flexible working area adaptation of the device. Furthermore, the solution defined creates possibilities to construct the device so that one of the link devices could be connected to, in the first instance, the base element via said hinge connection so that the movement of the link device at least in part becomes dependent on the movement of at least one other link device. This involves a difference relative to the device according to the US patent 4 976 582 where the three link devices are functionally independent of each other.

A number of advantageous developments of the invention are defined in the dependent claims. These developments and advantages in connection with the invention are dealt with more specifically in the following description.

SHORT DESCRIPTION OF THE DRAWINGS

With reference to the enclosed drawings a more close description of embodiment examples of the invention follows here under:

In the drawings:

- Fig 1 is a perspective view of a robot according to the invention in a diagrammatical form;
- Fig 2 is a view similar to Fig 1 but showing an alternative embodiment;
- Fig 3 is a further variant with respect to design;

Fig 4 is a detail view showing how, in the embodiment according to Fig 3, the device for providing pivoting of a link device may be designed;

Fig 5 is a partially cut, diagrammatical side view illustrating that a transmission for putting a working member on the moveable element in movement, here in rotation, may be incorporated into a link device extending between the two elements;

Fig 6 is a detail view according to the section VI-VI in Fig 5;

Fig 7 is a section along the line VII-VII in Fig 5;

Fig 8 is a view of a further variant with respect to the basic design of the robot;

Fig 9 shows a driving arrangement forming an alternative to the one illustrated in Fig 8;

Fig 10 shows, in perspective, a further robot alternative;

Fig 11 shows, in a view similar to the one in Fig 10, a robot embodiment of a somewhat more complex nature then the one in Fig 10;

Fig 12 is a perspective view of a further design variant;

Fig 13 is a perspective view of a further robot alternative;

Fig 14 is a view illustrating another design with regard to the connection of the link devices to the moveable element; and

Fig 15 is a perspective view illustrating an embodiment according to the invention having only two link devices.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In order to simplify the understanding, like reference characters have been used in the following in different embodiments for similar or corresponding components but with addition of letters specific to embodiments.

The robot illustrated in Fig 1 is intended for relative displacement of two elements 1, 2. The element 1 is in this example intended to form a base element, relative to which the element 2

is intended to be positioned in space. The element 2 is intended to carry, either directly as indicated in Fig 1, or indirectly via a carrying arrangement, a working member 3.

Link devices generally denoted 4, 5 and 6 respectively are coupled between the elements 1 and 2. Each of these link devices comprises at least two mutually articulated link units. With respect to the link device 4, these link units are denoted 7 and 8 respectively. With respect to the link device 5, they are denoted 9 and 10 respectively. Finally, with respect to the link device 6, they are denoted 11 and 12 respectively.

Power exerting arrangements 13, 14, 15 are adapted to impart the respective link devices 4, 5, 6 pivoting movements for the purpose of changing the relative position between the elements 1, 2.

A first 4 of the link devices is connected to the element 2 via a hinge connection generally denoted 16 so that there are, on consideration of the device in its entirety, at least two degrees of freedom in the form of relative pivotability about two pivot axes, real or imaginary, placed at an angle relative to each other between said first link device 4 and the element 2.

A further of the link devices, in the example the one denoted 5, is connected to the element 1 via a hinge connection generally denoted 17, said hinge connection providing for, on consideration of the device in its entirety, freedom of movement between said link device 5 and the element 1 as concerns at least two degrees of freedom consisting of pivotability about two different pivot axes.

With respect to the first of the link devices, namely the one denoted 4, the first link unit thereof has the character of a movement arrangement. Its second link unit 8 has, as will be explained in the following, the character of a more complex link arrangement. Between the movement arrangement 7 and the

link arrangement 8 there is a connection arrangement 18 interconnecting them. The movement arrangement 7 is provided between the connection arrangement 18 and the base element 1 whereas the link arrangement 8 is provided between the connection arrangement 18 and the moveable element 2.

The link arrangement 8 comprises at least two first links 19 connected relative to the connection arrangement 18 and the moveable element 2 via joints 20, 21 to be pivotable in all directions, said first links forming, together with the connection arrangement 18 and the moveable element 21, at least one first four-links system FS1. The movement arrangement 7 is adapted to allow relative movement between the connection arrangement 18 and the base element 1.

The link arrangement 8 comprises at least one third link 22 connected relative to the connection arrangement 18 and the moveable element 2 via joints 23, 24 to be pivotable in all directions. The joints 20, 21, 23, 24 of the first and third links 19, 22 are disposed in a triangular configuration. This means, accordingly, that the joints of the links 19, 22 at a respective end of the links may not be present on a straight line.

The third link 22, each of the first links 19, the connection arrangement 18 and the moveable element 2 form a third four-links system FS3.

The first links 19 are substantially equal in length. In addition, they are substantially parallel. The first and third links 19, 22 in the link arrangement 8 are substantially equal in length. Besides, they are substantially parallel.

The movement arrangement 7 is formed by a second link arrangement comprising at least one second link 25 pivotable relative to the connection arrangement 8 and base element 1. More specifically, the link arrangement 7 comprises at least two

second links 25, 26, which together with the connection arrangement 18 and the base element 1 form a second four-links system FS2. The links 25, 26 are substantially equal in length and substantially parallel. Thus, they form a parallelogram. This is pivotable in its own plane by means of the power exerting arrangement 13. This arrangement comprises a power exerting member 27 adapted to put the link 25 in a pivoting movement about an axis denoted 28. On pivoting of the link 25 about the axis 28, the link 26 will pivot about the axis 29 and furthermore, relative pivoting of the links 25, 26 and the connection arrangement 18 will occur via the axes 30, 31. In this case the joints denoted 28-30 form only one degree of freedom, i.e. a pure pivoting movement.

The link unit 9 of the second link device 5 is pivotably connected to a link contained in the second four-links system FS2 via a joint 33 forming a pivot axis 32 with one degree of pivoting, i.e. pure pivotability, relative to said link. Thus, the joint 33 will be moved together with the link on pivoting of said link. Although the joint 33 may be provided on each of the moveable links 25, 26 and the link in the four-links system FS2 formed by the connection arrangement 18 to be moved on movement of the four-link system, it is illustrated in the example that the joint 33 is arranged on the link denoted 25 and, more specifically, between the pivot axes 28, 30 thereof. The joint 33 should always be placed at a distance from the pivotable connections of the links 25, 26 to the base element 1 via the axes 28, 29. The pivot axis 32 of the joint 33 is substantially parallel to the pivot axes in the four-links system FS2.

Thus, the hinge connection 16 is formed by the joints 21 and 24. These individual joints each provide for at least two degrees of freedom in the form of pivotability about two different pivot axes. The joints 21 and 24 could be formed by ball joints, in which case also a third degree of freedom in the form of rotation could

be present, or cardan joints. Corresponding considerations are valid with respect to the joints 20 and 23.

The link device 5 comprises the first link unit 9, which will be moveable relative to the base element 1 with two degrees of freedom, namely pivoting movements about the separated axes 28 and 32. This means the desirable consequence that a change in form of the four-links system FS2 will cause the link unit 9 and, accordingly, the link device 5 to accompany, a fact which simplifies control of the robot and increases the working area.

Besides, the link device 5 comprises a further link unit 10. This is connected to the moveable element via a hinge connection 34, which on consideration of the device in its entirety provides for freedom of movement between the link device 5 and the moveable element 2 with respect to at least two degrees of freedom consisting of pivotability about two different pivot axes. Also here, the hinge connection 34 may be formed by joints 35 in the form of ball joints, cardan joints etc providing for two or possibly three degrees of freedom. In the example, the link unit 10 is formed by two links 36, which via the joints 35 are connected to the moveable element 2 and via joints 37 are connected to the link unit 9. This link unit 9 is in the example formed by one single link, which at its end turned away from the joint 33 is connected to the link unit 10 via a connection providing, as viewed in the assembled state of the device, at least two degrees of freedom in the form of pivotability about two different pivot axes, real or imaginary. For instance, the joints 37 could consist of ball joints or cardan joints. In case the links 36 are connected to a cross piece 38, which in its turn is rotatably connected with one degree of freedom to the link 9, the joints 37 could consist of simple joints having a single degree of freedom involving pivotability about axes forming an angle to the axis of rotation of the cross piece 38 relative to the link 9.

The links 36 are substantially parallel and substantially equal in length and form, accordingly, a forth four-links system FS4. From that stated it appears that the link 9 in the example will pivot in parallel with the links 25, 26. Thereby the link devices 4 and 5 will be able to hold the moveable element 2 in one and the same orientation, i.e. in parallelism with the connection arrangement 18 in the entire working area.

To achieve pivoting of the link 9, a power exerting member 39 of the power exerting arrangement 14 acts on the link 9 via a transmission 40 extending from the power exerting member 39 on the base element 1 to the link 9 in the link device 5. More specifically, the transmission 40 comprises in the example a flexible traction force transmitting element 41 laid about diverting members, a first 42 of which is connected to an output axle of the power exerting member 39 formed as a rotary means so as to be prevented from rotation relative to the output axle and a second 43 of which is connected to the link 9 so as to be prevented from rotation relative thereto. Thus, by driving the rotary means 39 in opposite directions, the link 9 may be pivoted in a desired direction relative to the link 25.

The further link device 6 has in the embodiment according to Fig 1 only the function to cause the second element 2 to move in Y-direction, i.e. in a direction substantially transversely to the plane of pivoting of the four-links system FS2.

The variant illustrated in Fig 2 differs from the one in Fig 1 by the link 9a here being adapted to be pivoted relative to the link 25a via a transmission 40a, which is not based upon traction force transmitting elements of a flexible type but instead comprises two links 44 articulated relative to each other, one of said links being connected to the rotor of the rotary means 39 so as to be prevented from rotation relative thereto whereas the second is pivotably connected to the link 9a. It is preferred, in both Figs 1 and 2, that the output axle of the rotary means 39a is

concentric to the pivot axis 28 of the power exerting member 13. Otherwise the link 9a is as before pivotably articulated relative to the link 25a so that the link 9a will be moveable relative to the base element 1a with two degrees of freedom.

In the variant according to Fig 3, the link 9b of the link device 5b is no longer moveable relative to the base element 1b with two degrees of freedom but only with a single one as a consequence of the power exerting member 39b being, with a stationary portion, rigidly connected to the base element 1b and, with a moveable portion, rigidly connected to the link 9b so that the latter will move relative to the base element 1b with one single degree of freedom, which in the proceeding embodiment is formed by a pivoting movement since the power exerting member 39b here is illustrated as a rotary means, with the rotor of which the link 9b is rigidly connected.

In the embodiment according to Fig 1, the link unit 11 of the link device 6 is moveable with one single degree of freedom in the form of a pure pivoting movement relative to the base element 1 as a consequence of the design of the power exerting arrangement 15 as a rotary means having a stator connected to the base element 1 and a rotor rigidly connected to the link unit 11 formed as one single link. The link unit 12 according to Fig 1 has likewise the character of a single link and is with the ends thereof rigidly connected to the link 11 and to the moveable element 2 via hinge connections 45 and 46 respectively allowing at least two degrees of freedom in the form of pivoting about axes placed at an angle relative to each other, which may be realised by the joints 45, 46 being formed as ball joints, in which case three degrees of freedom are present as a consequence of the additional possibilities to rotation, or cardan joints.

In the variant according to Fig 3, there is the difference that the links 11b and 12b are mutually connected via a hinge connection 47 allowing one single degree of freedom in the form of

pivoting between the links. On the contrary, the link 11b is moveable, via a hinge connection generally denoted 48, with two degrees of freedom relative to the base element 1b in contrast to the preceding embodiment. As concerns the link 12b, the same is, however, connected to the moveable element 2b via a joint 46b which here must present three degrees of freedom, namely two degrees of freedom in the form of pivoting about axes placed at an angle to each other and a further degree of freedom in the form of rotation about the longitudinal axis of the link 12b.

Fig 4 illustrates more specifically in a detail view from above of the hinge connection 48 per se that the link 11b is rigidly connected to a gear wheel 49 comprised in an angular gear. The link 11b is pivotably supported relative to the base element 1b about a first axis 50. The gear wheel 49 is in engagement with a second gear wheel 51, which is connected to a rotor of the power exerting arrangement 15b so as to be prevented from rotation relative to said rotor, the power exerting arrangement being formed as a rotary means having a stator connected to the base element 1b and a rotor connected to the gear wheel 51. Said rotor has the character of an output axle. The link 11b is pivotable relative to the base element 1b about a second axis 52 extending at an angle, in particular a substantially right angle, to the first mentioned axis 50. Said pivotability about the axis 52 is formed by a yoke 53 being rotatably supported about the output axis of the rotary means 15b and this yoke 53 carries in its turn the axis, around which the link 11b is pivotable.

The embodiment according to Figs 3 and 4 has the advantage that when the moveable element 2b is moved in the direction x by the link device 5b, the link device 6b will accompany while being inclined as a consequence of rotation about the axis 52. This means that the link device 6b always will have a favourable orientation for executing control forces on the moveable element 2b.

Figs 5-7 illustrate a link device 6c corresponding to the one denoted 6b in Fig 3. As in the preceding embodiment, this link device comprises links 11c, 12c. Along this link device there is provided a transmission generally designated 54 for transmitting driving power between a power exerting member 55 arranged on the base element 1c and a working member 3c arranged on the moveable element 2c. More specifically, the transmission 54 is adapted to rotate the working member 3c, e.g. about its own axis. The transmission 54 comprises traction force transmitting elements 56, 57 laid around diverting members 58, 59, 60 disposed at the articulated connection 47c of the links 11c and 12c and at the ends of the links 11c and 12c turned away from the connection 47c. The diverting member 59 on the link 11c is drivingly connected, via an angular gear 61, to an output drive axle 62 from the power exerting member 55. Around this drive axle 62 there is arranged a tubular axle 63, with which gear wheels 64 and 65 respectively are rigidly connected. The gear wheel 64 is in driving engagement with a gear wheel 66 placed on an output axle from the power exerting member 15c in the form of a rotary means. The gear wheel 65 is included in an angular gear together with a further gear wheel 67, which is connected to the link 11c so as to be prevented from rotation relative thereto. When the rotary means 15c is operated, the tubular axle 63 will, via the gear wheels 66 and 64, rotate about the axle 62 and this puts, via the gear wheel 65, the gear wheel 67 rigidly connected to the link 11c in rotation about an axle 68. This axle is arranged in an attachment 69 which is rotatably supported about an axis parallel to the axle 62 and the tubular axle 63, more specifically by the attachment 69 being rotatably supported about a portion of the tubular axle 63. This means that the link 11c will be able to pivot relative to the base element 1c about the axle 68 and an axle perpendicular in relation to this axle 68 and concentric to the axle 62. Thus, there are two degrees of freedom for the link 11c in accordance with the preceding embodiment.

At that end of the link 12c which is closest to the moveable element 2c, a gear wheel 70 is connected to the diverting member 60 so as to be prevented from rotation relative thereto, said gear wheel 70 being included in an angular gear since it is in engagement with a further gear wheel 71, which is rigidly connected to an axle 72, to which also a further gear wheel 73 is connected. This gear wheel 73 is contained in a further angular gear since it is in engagement with the gear wheel 74, which is connected to the working member 3c so as to be prevented from rotation relative thereto.

It appears from Fig 7 that a yoke like attachment 75 operates as a carrier for an axle 76, around which the link 12c is pivotable relative to the moveable element 2c. This attachment 75 is in its turn pivotably arranged around an axis extending at an angle, preferably a substantially right angle, to the axle 76, in the example the axle denoted 72 and carrying the gear wheels 71 and 73. Thus, there are between the link 12c and the moveable element 2c two degrees of freedom in the form of pivotability around double pivoting axes relative to the moveable element 2c, said pivoting axes extending at an angle to each other. On operation of the rotary means 55, the axle 62 and the gear wheel 77 placed thereon and comprised in the angular gear 61 will be put into rotation and this causes rotation of the gear wheel 78 rigidly connected to the diverting member 59. Thus, this causes the traction force transmitting element 56 to be driven around, a fact which puts the diverting member 58 in rotation. This is in engagement with the traction force transmitting element 57, which means that also the diverting member 60 and the gear wheel 70 rigidly connected thereto are put into rotation. This rotation is, via the angular gears 70/71 and 73/74, transferred into rotation of the working member 3c.

The embodiment according to Figs 5-7 has the advantage that both power members 55 and 15c for pivoting the working mem-

ber and pivoting the link device 6c may be disposed on the base element 1c so that a minimum of mass inertia is achieved.

Fig 8 illustrates a variant where the link device 5d as in the embodiment according to Fig 3 has a link 9d, which is put into motion, by means of the power exerting member 39d, in a movement with only one degree of freedom, namely a pure pivoting movement. A power exerting member 15d serves for putting the link 11d of the link device 6d into a pivoting movement about an axle 77. The movement of the link 11d relative to the power exerting member 15d occurs with one single degree of freedom. However, the power exerting member 15d is in this case adapted to be put into a rotational movement of the power exerting member 39d belonging to the link device 5d in that a base of the power exerting member 15d is connected to the output axle of the power member 39d. Said output axle from the power member 39d extends substantially perpendicularly relative to the axis 77. Thus, the link 11d will be moveable relative to the base element 1d with two degrees of freedom, i.e. pivoting movements around double pivot axes inclined relative to each other. This means that when the link 9d is pivoted by means of the power member 39d, the power member 15d and then also the link 11d will accompany. The joint 45d between the links 11d and 12d as well as the joint 46d between the link 12d and the moveable element 2d are designed to allow at least two degrees of freedom in the form of pivoting around axes placed at an angle to each other. The embodiment according to Fig 8 makes it possible to rationally provide a transmission extending along the links 11d and 12d to cause the working member 3d to rotate. This transmission may for instance be based on use of axles and cardan joints.

Fig 9 illustrates a variant of the embodiment according to Fig 8. According to this variant, both of the power exerting members 15e and 39e will be capable of being arranged on the base element 1e so that the mass inertia becomes minimal. More spe-

cifically, the power exerting member 39e acts on the link 9e by an output axle from the power member comprising a gear wheel 78 in engagement with a gear wheel 79 rigidly connected to an axle 80, to which also the link 9e is rigidly connected. The axle 80 is designed as a tubular axle and receives an axle 81, which is in driving connection with the power exerting member 15e. A gear wheel 82 is connected to the axle 81 so as to be prevented from rotation relative thereto and this gear wheel 82 as well as a further gear wheel 83 rigidly connected to the link 11e forming an angular gear to subject the link 11e to pivoting movement around an axle 68e. An attachment 84 carries the axle 68e and is connected to the tubular axle 80 so as to be prevented from rotation relative thereto in order to be put into a rotation about the axle 81 together with the tubular axle 80 by means of the power exerting member 39e. As in the embodiment according to Fig 8, link 11e will accompany on pivoting of the link 9e.

Fig 10 illustrates a variant deviating from the one in Fig 8 by the power member 39h here having a stationary portion secured to the base element 1h without any direct connection to the power exerting member 39h for the link device 6h. Instead, the power member 15h is here rotatably supported with a base portion relative to the base element 1h about an axle 92. A moveable portion of the power member 15h is rigidly connected to the link 11h. Accordingly, the link 11h will be moveable relative to the stationary portion of the power member 15h with one single degree of freedom, namely pure pivoting, whereas the power member 15h will be moveable relative to the base element 1h with a further degree of freedom, namely pure pivoting, and this more specifically about an axis extending at an angle to the pivot axis of the link 11h relative to the base portion of the power member 15h. The effect of this is that the link 11h will be moveable relative to the base element 1h with two degrees of freedom. When the link device 5h is pivoted with assistance of the power member 39h, the link device 6h will be able to accompany by the base portion of the power member 15h rotating

about the axle 92. The interconnection between the link device 5h and 6h in this regard occurs by means of a connection link 93, which connects, by means of hinge connections having at least two degrees of freedom, i.e. pivoting about axles angled relative to each other, the link devices. For the rest, the embodiment is as previously described.

Fig 11 illustrates a variant of the embodiment according to Fig 10. The difference is a.o. that the four-links system FS2 has been arranged pivotable about an axle 94 relative to the base element 1i. Between the four-links system FS2 and the connection arrangement 18i there is also rotatability about an axle 95. The axles 94, 95 are substantially parallel to each other. In order to maintain the orientation of the connection arrangement 18i relative to the base element 1i, there is between the base element and the connection arrangement 18i a further link 96, which forms, with the four-links system FS2, a further four-links system, which on pivoting of the four-links system FS2 will maintain the orientation of the connection arrangement 18i relative to the base element 1i. The further link 96 must be connected to the base element 1i and the connection arrangement 18i, via joints having at least two degrees of freedom. In contrast to the preceding embodiment, the power exerting member 15i is here arranged directly on the base element 1i so that the link 11i will describe a movement having only one degree of freedom relative to the base element 1i, namely in the example pure pivoting. In the embodiment according to Fig 11, the individual link 9 in the preceding embodiment has been replaced with a link unit 9i forming a four-links system. This four-links system is, by means of the power member 39i, pivotable relative to the base element 1i in a plane of pivoting orientated substantially perpendicularly to planes, in which the four-links system 9i is possible to change as to form. The four-links system 9i is then connected to the link unit 10i which also is designed as a four-links system. In this case there are between the link 11i in the link device 6i and the connection arrangement

18i and the four-links system 9i links 97 and 98 respectively, which cause the connection arrangement 18i and the four-links system 9i to be able to accompany when the link 11i is pivoted by means of the power member 15i.

The variant according to Fig 12 is in reality equivalent to the one in Fig 10. However, the link 93j is here coupled between the links 9j and 11j respectively whereas the power member 15j is provided on the base element 1j. A moveable portion of the power member 15j is connected to the link 11j to pivot the same. This moveable portion denoted 99 is, however, rotatably co-ordinated with the link 11j so that when the link 9j is pivoted by means of the power member 39j, the link 11j will be able to accompany freely in pivoting movements substantially parallel to the pivot axis for the moveable portion 99 but when the power member 15j is activated, the moveable portion 99 thereof will, on rotation, force the link 11j to accompany. However, there is also here as appears from the description, a freedom of movement between the link 11j and the base element 1j having regard to two degrees of freedom, namely pivotability about double pivot axes angled relative to each other.

The variant according to Fig 13 differs mainly from the one in Fig 11 by FS2 and the further link 96 being operated in altitude by means of a further link device 100, which operates as a power intermediary between a power exerting member 101 and the connection arrangement 18k. The link device 100 comprises a link arm 102 which is moveable with one single degree of freedom, in the example pure pivoting, relative to the base element 1k and which via a four-links system 103 similar to the one previously denoted 10 is connected to the connection arrangement 18k. The four-links system 103 could also engage on links forming a connection between the base element 1k and the connection arrangement 18k. Between the connection arrangement 18k and the link 11k in the link device 6k there is a connection 104 connecting together the pivoting movement of the link 11k

with the connection arrangement 18k so that the later is displaced when the link 11k is pivoted.

The variant in Fig 14 corresponds substantially to what has been described earlier with the exception that the links 191 and 221 here are connected to sleeves 105 and 106 respectively via joints having one single degree of freedom, namely in the embodiment freedom to pivot about one single axis. These sleeves 105, 106 are in their turn rotatably journalled about axles 107 and 108 respectively. The axle 108 is conceived to form a constituent of the moveable member 11, at which the working member 31 is arranged. The moveable member 11 is rotatably journalled around the axle 107. The link device 61 acts on the axle 107 in a manner which in principle already has been described. The purpose of the embodiment according to Fig 14 is most closely to demonstrate that many variants are possible when it comes to realise the hinge connection between the links and other constituents contained in the robot structures. The applications in question are, accordingly, only restricted by the definitions appearing from the appendant patent claims.

Fig 15 illustrates a variant deviating from the one in Fig 1 in the sense that here the link devices 5 and 6 present in Fig 1 have been replaced by one single link device 5m. This is coupled, with a first link unit 10m, to the moveable element 2m via a connection 109 comprising one single degree of freedom, namely pivoting about one single axis. In the example it is illustrated that the link unit 10m comprises only one single link. It should be understood that two or more links may be arranged in parallel to improve stability if this would be desired.

The link device 5m comprises, furthermore, a link unit 9m which is connected to the link unit 10m with two degrees of freedom, i.e. in the example pivoting about double axes placed at an angle relative to each other. Although said two degrees of freedom may be realised with cardan joints or similar, a cross piece 38m as in Fig 15 may also be moveable with one degree of freedom

relative to the link 10m, i.e. by pure rotation whereas this cross piece then is connected to the two links 110 comprised in the link unit 9m via joints 111 also comprising one single degree of freedom, i.e. pure pivotability but this about axes which are angled relative to the axis, around which the cross piece 38 is pivotable relative to the link 10m.

The links 110 are then also connected to the base element 1m via two degrees of freedom. More specifically, a cross piece 112 is in the example rotatably supported relative to the base element 1m with one single degree of freedom and then the links 110 are hingedly connected to this cross piece 112 also with one single degree of freedom, namely pure pivoting. The pivoting of the links 110 relative to the cross piece 112 occurs around axles placed at an angle relative to the axis of rotation of the cross piece 112 relative to the base element 1m.

It should be observed that it is essential in the embodiment according to Fig 15 that the parallelogram formed by the links 110 and the cross pieces 38m and 112 is rigid to rotation, i.e. that the cross pieces 112 and 38m comprised in the parallelograms are maintained substantial parallel, the link 10m between the moveable element 2m and the cross piece 38m also being allowed to have one single degree of freedom in the form of pure pivotability in order to achieve stabilisation of the moveable element 2m.

Furthermore, it is pointed out that the four-links system FS2 also must be secured against rotation, i.e. adapted to be able to change its form in substantially one and the same plane.

In order to operate FS2, there is as before a power exerting arrangement 13m. In order to execute required control via the link device 5m, a power exerting member 39m is adapted to pivot the cross piece 112 and in this way pivot the links 110 relative to the base element 1m whereas a further power exerting mem-

ber 15m is adapted to pivot the links 110 relative to the cross piece 112 in planes substantially parallel to the axis of rotation of the cross piece 112. It is illustrated in the example that the power exerting member 39m has a stationary portion connected to the base element 1m and a moveable portion connected to the cross piece 112. The power exerting member 15m is, in the example, illustrated as comprising a stationary portion rigidly connected to the cross piece 112 whereas a moveable portion of the power exerting member is connected to one of the links 110. Expressed in other words, the links 110 may be operated in two planes substantially perpendicular to each other by means of the power members 39m and 15m.

Common to all described embodiments is that a suitable control unit, particularly in the form of a computer, is adapted to control the power exerting members of the various robot embodiments for the purpose of causing the second element 2 or members coupled thereto directly or indirectly to move in desired paths.

POSSIBLE MODIFICATIONS

It is evident that the invention is not only restricted to the embodiments discussed herein above. Thus, detail adaptations of the embodiments may be carried out depending on the circumstances without leaving the inventive concept appearing from claim 1.

CLAIMS:

1. A device for relative movement of two elements (1, 2), one of said elements forming a base element whereas a second is movable restive to the first, comprising at least two link devices (4, 5, 6) coupled between the elements, each of said link devices comprising at least two mutually articulated link units, and a power exerting arrangements (13, 14, 15) provided to impart the link devices pivoting movements for the purpose of changing the relative position of the elements, a first (4, 5 or 6) of the link devices being connected to one (2 or 1) of the elements via a hinge connection so that when considering the device in its entirety there are, between said first link device and said element, at least two degrees of freedom in the form of relative pivotability about two pivot axes, real or imaginary, forming an angle relative to each other, **characterized** in that a further (4, 5 or 6) of the link devices is connected to another (1 or 2) of the elements via a hinge connection which provide for, when the device is considered in its entirety, freedom of movement between said further link device and said another of the elements as concerns at least two degrees of freedom consisting of pivotability about two different pivot axes, real or imaginary.

2. A device according to claim 1, **characterized** in that the first (4) of the link devices comprises a link arrangement (8), a movement arrangement (7) and a connection arrangement (18) interconnecting the link arrangement and the movement arrangement, the movement arrangement being provided between the connection arrangement and one (1) of the elements whereas the link arrangement (8) is arranged between the connection arrangement (18) and another (2) of the elements.

3. A device according to claim 2, **characterized** in that the link arrangement (8) comprises at least two first links (19) con-

nected via joints relative to the connection arrangement and the associated of the elements to be pivotable in all directions, said first links forming, together with the connection arrangement and the associated of the elements, at least one first four-links system (FS1), the movement arrangement being adapted to allow relative movement between the connection arrangement and the associated of the elements.

4. A device according to claim 3, **characterized** in that the power exerting arrangements (13, 15, 39) comprise arrangements to actuate the link arrangement and the movement arrangement so as to change the relative position of the elements.

5. A device according to claim 3, **characterized** in that the link arrangement (8) comprises at least one third link (22) connected via joints relative to the connection arrangement and the associated of the elements to be pivotable in all directions and that the joints (20, 21, 23, 24) of the first and third links are disposed in a triangular configuration.

6. A device according to claim 5, **characterized** in that the third link (22), each of the first links (19), the connection arrangement (18) and the associated (2) of the elements form a third four-links system (FS3)

7. A device according to claims 3 and 6, **characterized** in that the first links (19) in the link arrangement are substantially equal in length.

8. A device according to claims 3 and 6, **characterized** in that the first links (19) in the link arrangement are substantially parallel.

9. A device according to any of claims 2-8, **characterized** in that the movement arrangement (7) is formed by a second

link arrangement comprising at least one second link (25, 26) pivotable relative to the connection arrangement and the associated of the elements.

10. A device according to claim 9, **characterized** in that the second link arrangement (7) comprises at least two second links (25, 26), which together with the connection arrangement (18) and associated (1) of the elements form a second four-links system (FS2).

11. A device according to claim 10, **characterized** in that the second links (25, 26) in the second link arrangement (7) are substantially equal in length.

12. A device according to claim 11, **characterized** in that the second links (25, 26) in the second link arrangement are substantially parallel.

13. A device according to claim 3 and 6, **characterized** in that the first and third links (19, 22) in the first link arrangement are substantially equal in length.

14. A device according to claim 13, **characterized** in that the first and third links (19, 22) in the first link arrangement are substantially parallel.

15. A device according to any preceding claim, **characterized** in that the further link device (5 or 6) is connected to another (4 and 5) respectively of the link devices by connection means (33, 33a, 80, 84, 93, 97, 98, 93j, 104,113) to accompany said another of the link devices in its movement resulting of its associated power exerting arrangement (15 and 13) respectively.

16. A device according to claim 15, **characterized** in that the further link device (5 or 6) is hingely connected to a move-

able part (25, 9d, 9e, 5h, 9i, 9j, 18k) comprised in said another (4 and 5) respectively of the link devices.

17. A device according to claim 16, **characterized** in that the moveable part is pivotable.

18. A device according to any of claims 16-17, **characterized** in that the power exerting arrangement (14) belonging to the further link device (5) is adapted to cause a link unit (9) comprised in the further link device (5) to pivot relative to the moveable part (25).

19. A device according to any of claims 10-12, **characterized** in that the further link device (5) is pivotably connected, at one of its ends, to a moveable link (25) comprised in the second four-links system.

20. A device according to claim 19, **characterized** in that the further link device (5) is pivotably connected to the link (25) of the second four-links system about a pivot axis (32) which is substantially parallel to a pivot axis (28) of this link relative to the associated of the elements.

21. A device according to claim 17, **characterized** in that the further link device (5) comprises at least one first link (9) pivotably connected to said link (25) of the second four-links system and at least one second link (36) connected to the second (2) of the elements in a pivotable manner.

22. A device according to claim 21, **characterized** in that a power exerting arrangement (39) to cause the first link (9) in the second link device (5) to pivot relative to the link (25) of the second four-links system (FS2) comprises a power exerting member (39) arranged on that (1) of the elements to which the link (25) of the second four-links system is pivotably connected.

23. A device according to claim 22, **characterized** in that said power exerting member (39) acts on the first link of the further link device via a transmission (40) comprising power transmission members (41) extending along the link (25) of the second four-links system.

24. A device according to claim 22, **characterized** in that the power exerting member (39a) acts on the first link (25a) of the further link device via a link arm system (40a) comprising at least two articulated links (44).

25. A device according to claim 1, **characterized** in that the further link device (4, 5, 6) is connected to both of the elements via hinge connections, which on consideration of the device in its entirety allow relative movements with two degrees of freedom between said further link device and each of the elements.

26. A device according to claim 25, **characterized** in that links (11b, 12b) comprised in the further link device (6b) are hingedly connected to each other via a hinge connection (47) allowing one single degree of freedom of movement in the form of pivoting between the links.

27. A device according to claim 25 or 26, **characterized** in that a power exerting arrangement (15, 6, 15c) to cause the further link device (6b, 6c) to pivot relative to the elements comprises a power exerting member (15b, 15c) arranged on one of the elements in the form of a rotary means, which via an angular gear (49, 51; 65, 67) comprising a gear wheel (49, 67) rigidly connected to one of the links (11b, 11c) in the second link device is capable of transmitting drive power to said link, and that this link is freely pivotable about an axis (52, 62) substantially parallel to the axis of rotation of the rotary means.

28. A device according to any of claims 25-27, **characterized** in that a transmission for driving power transmission between a power exerting member (55) arranged on one of the elements and a working member (3c) arranged on the second of the elements is provided along the further link device (6c).

29. A device according to claim 28, **characterized** in that the transmission comprises traction force transmitting elements (56, 57) laid about diverting members (59, 58, 60) rotatably provided at the articulated connection of the links of the further link device and at that end of at least one of the links which is turned away from the articulated connection, and that the diverting member present at at least one of the ends, which are turned away from each other, of the links comprised in the further link device is drivingly coupled, via an angular gear, to the power exerting member or working member (3c).

30. A device according to claim 29, **characterized** in that the power exerting member (55) to cause one of the diverting members (59) to rotate is formed by a rotary means (55) having an axle (62), on which there is arranged a gear wheel (77) drivingly engaged with a gear wheel (78) connected to the diverting member, said two gear wheels forming an angular gear, and that a tubular axle (63) is arranged about said axle and provided with means for driving via the power exerting member (15c) arranged for pivoting the second link device and a gear wheel in engagement with a gear wheel (67) rigidly connected to the adjacent link (11c) of the further link device, the two last mentioned gear wheels (65, 67) forming, in unison, the previously mentioned angular gear.

31. A device according to claim 23, **characterized** in that the power transmission members (40) comprise at least one flexible traction force transmitting element (41) and diverting members (42, 43), about which the element is laid, and that

the power exerting member (39) is adapted to put one of the diverting members in rotation whereas a second (43) of the diverting members is rigidly connected to the second link (9) of the further link device (5).

32. A device according to any preceding claim, **characterized** in that the further link device (4, 5, 6) is connected to the first of the elements with at least three degrees of freedom of movement.

33. A device according to any preceding claim, **characterized** in that two further link devices (5d, 6d) are present, that these further link devices each comprise a moveable first link capable of being put into movement by a power exerting arrangement and that the moveable link (11d) of one (6d) of the further link devices is arranged to be caused to accompany the moveable first link (9d) of the remaining (5d) of the further link devices in a movement involving one further degree of freedom.

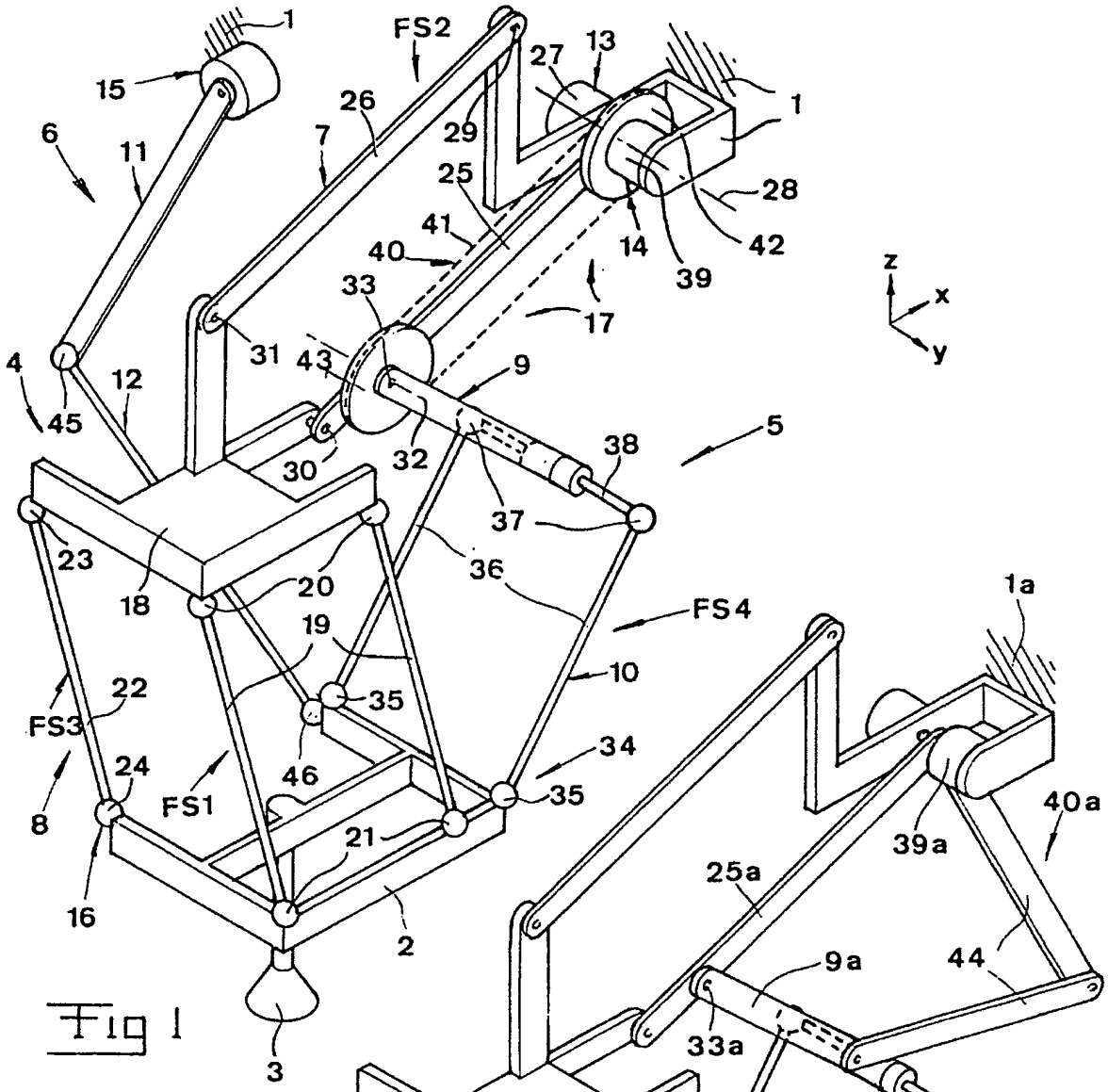
34. A device according to claim 2, **characterized** in that the movement arrangement (FS2, 96) is connected to the base element with connections providing two degrees of freedom.

35. A device according to claim 3 and 34, **characterized** in that the first four-links system (FS1) is rotatably connected to the base element about an axis (94) substantially parallel to a pivoting plane of the four-links system and that a further link (96) of the movement arrangement forms a further four-links system operating parallel controlling on the connection arrangement (18i).

36. A device according to claims 1-4, **characterized** in that the first link unit (9m) of the further link device (5m) is connected to the base element (1m) via a connection providing two degrees of freedom whereas the second link unit (10m) is con-

nected to the moveable element (2m) via a connection (10q) having one degree of freedom only and that the two link units (9m, 10m) are interconnected via a connection providing two degrees of freedom.

37. A device according to any preceding claim, **characterized** in that it is formed by an industrial robot, the second element (2) of which is intended to carry, directly or indirectly, at least one working member (3).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FS2
27
13
15
26
1
6
11
7
29
25
28
41
40
14
42
39
33
17
z
x
y
31
43
9
4
12
45
30
32
38
5
37
23
36
20
18
FS4
1a
19
10
22
35
FS3
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25a
16
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33a
3

Fig 1

Fig 2

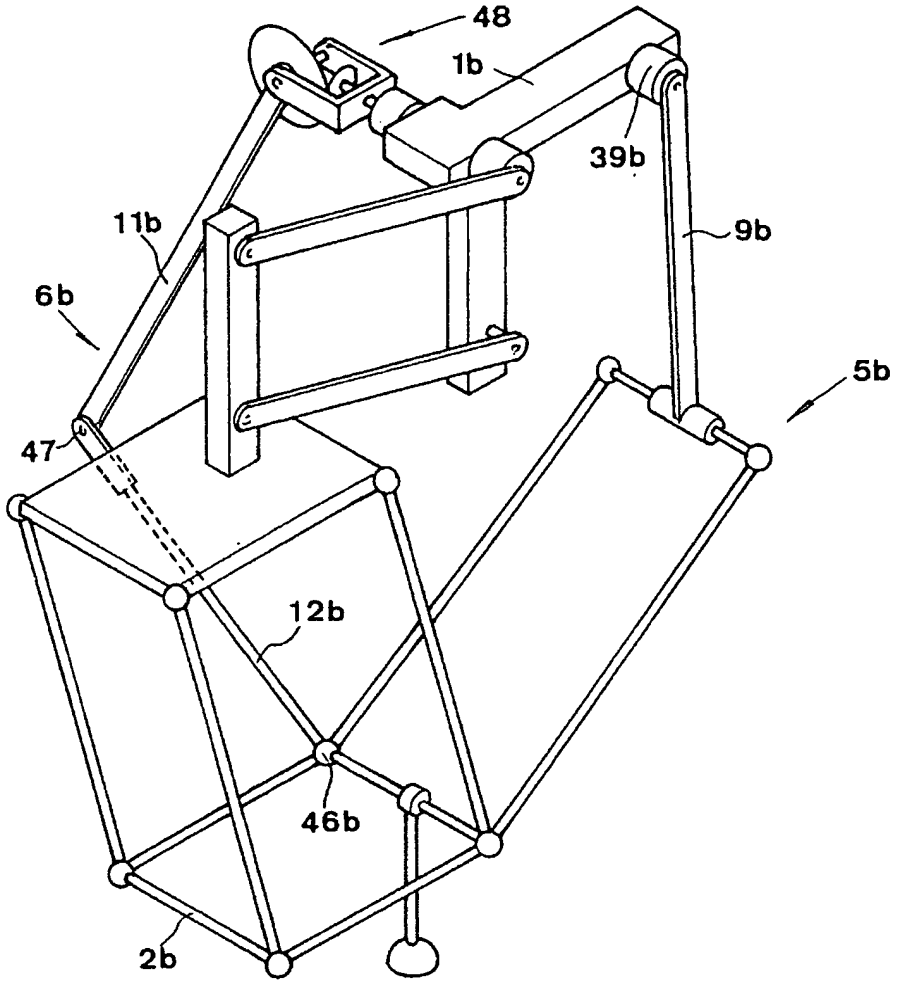


Fig 3

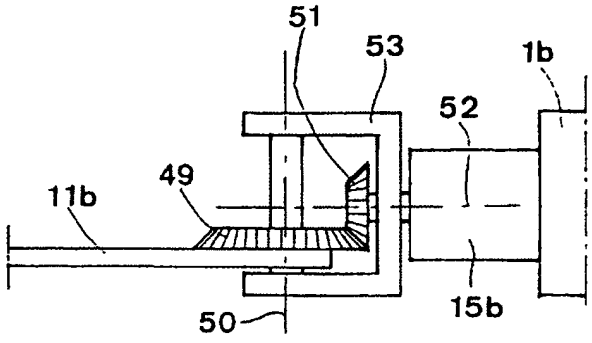


Fig 4

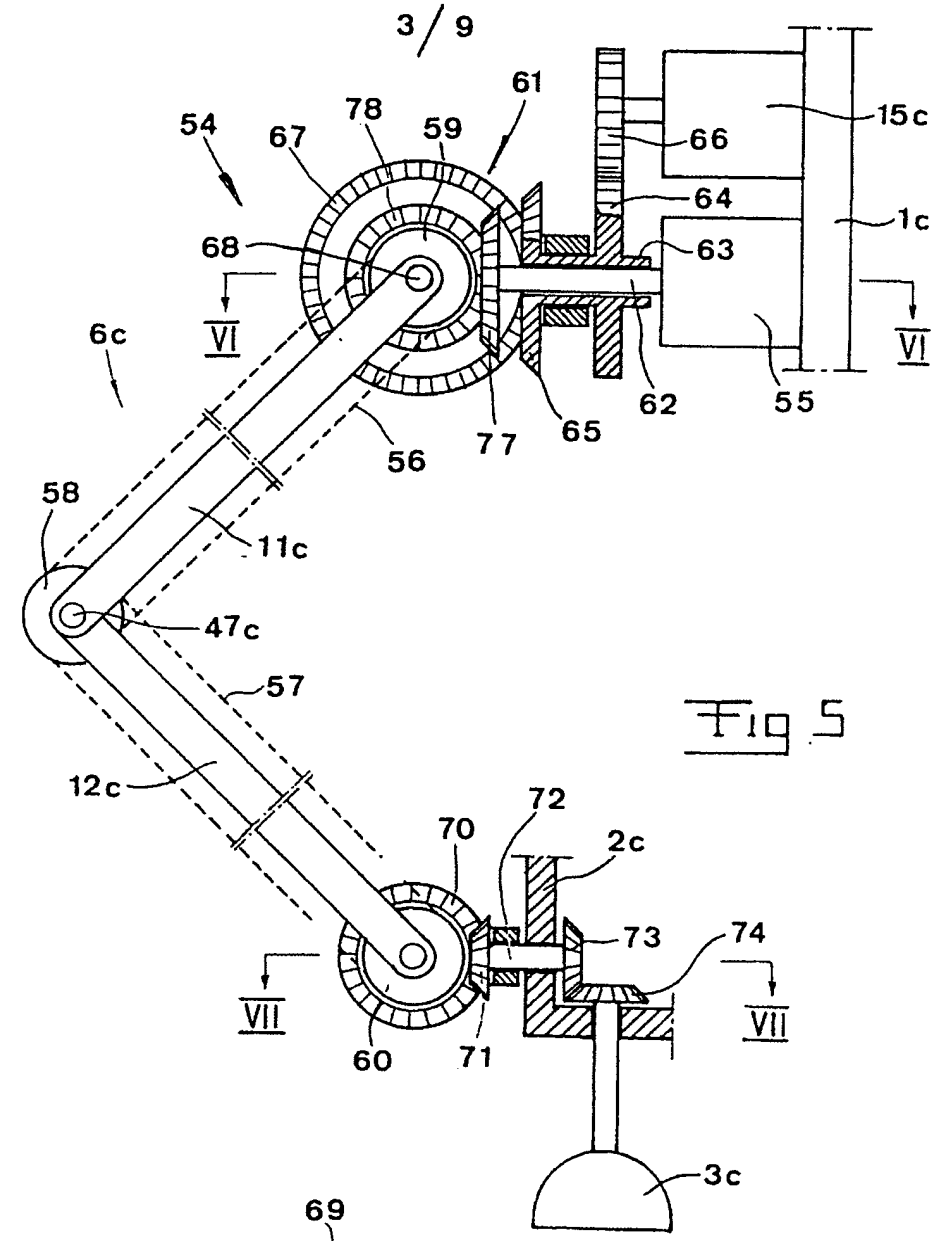


Fig 5

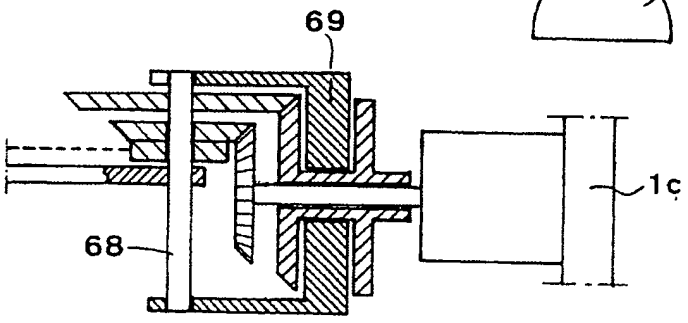


Fig 6

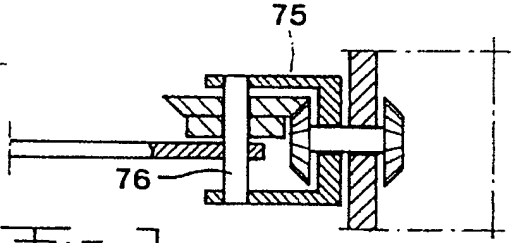
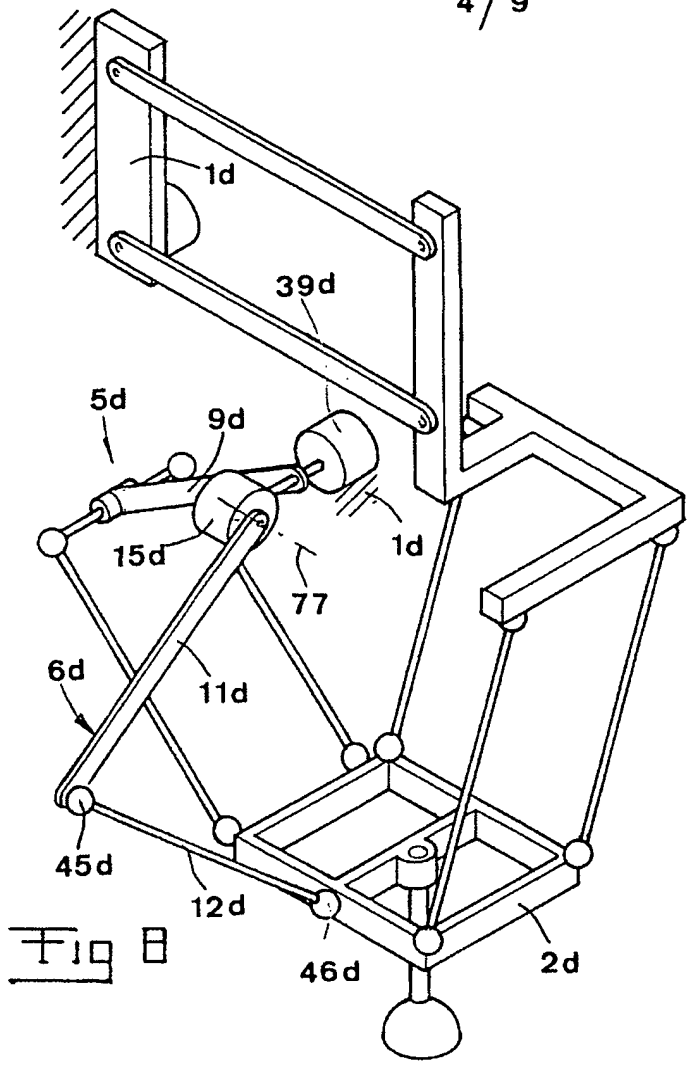


Fig 7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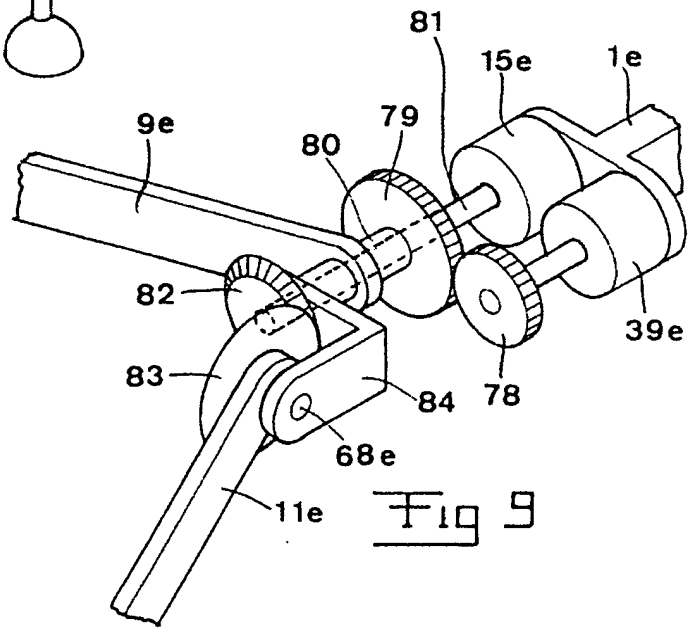
5d
9d
15d
1d
77
6d
11d
45d
12d
46d
2d

Fig 8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15e
1e
9e
80
79
82
39e
83
84
78
68e
11e

Fig 9

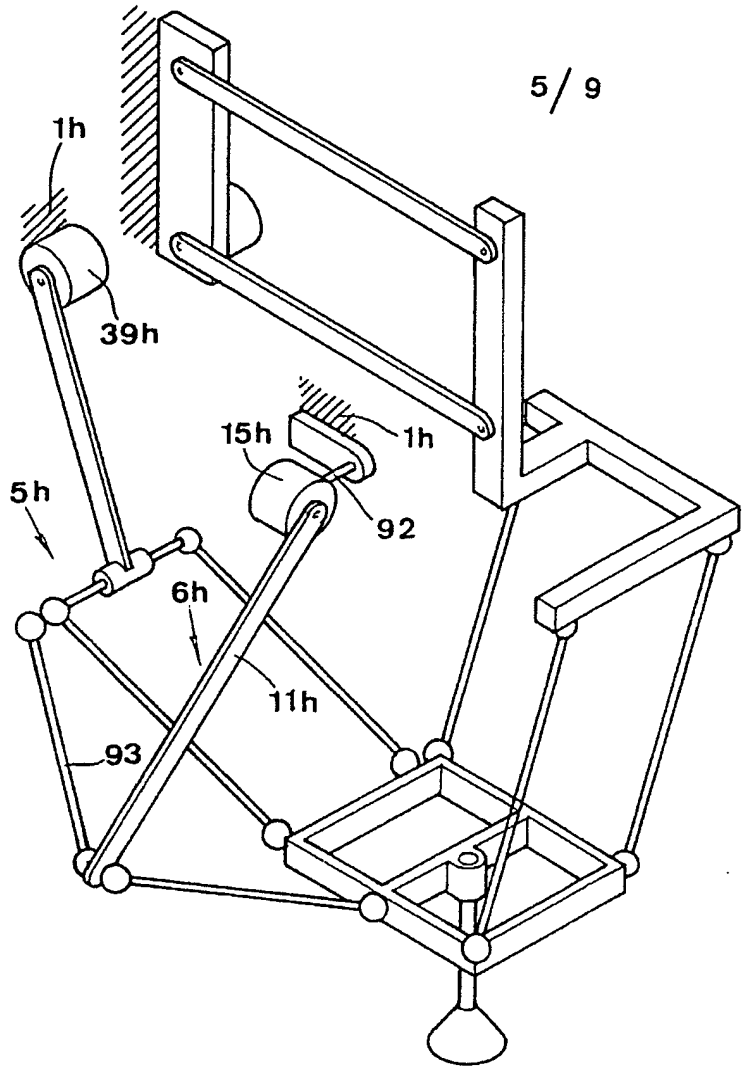

Fig 10

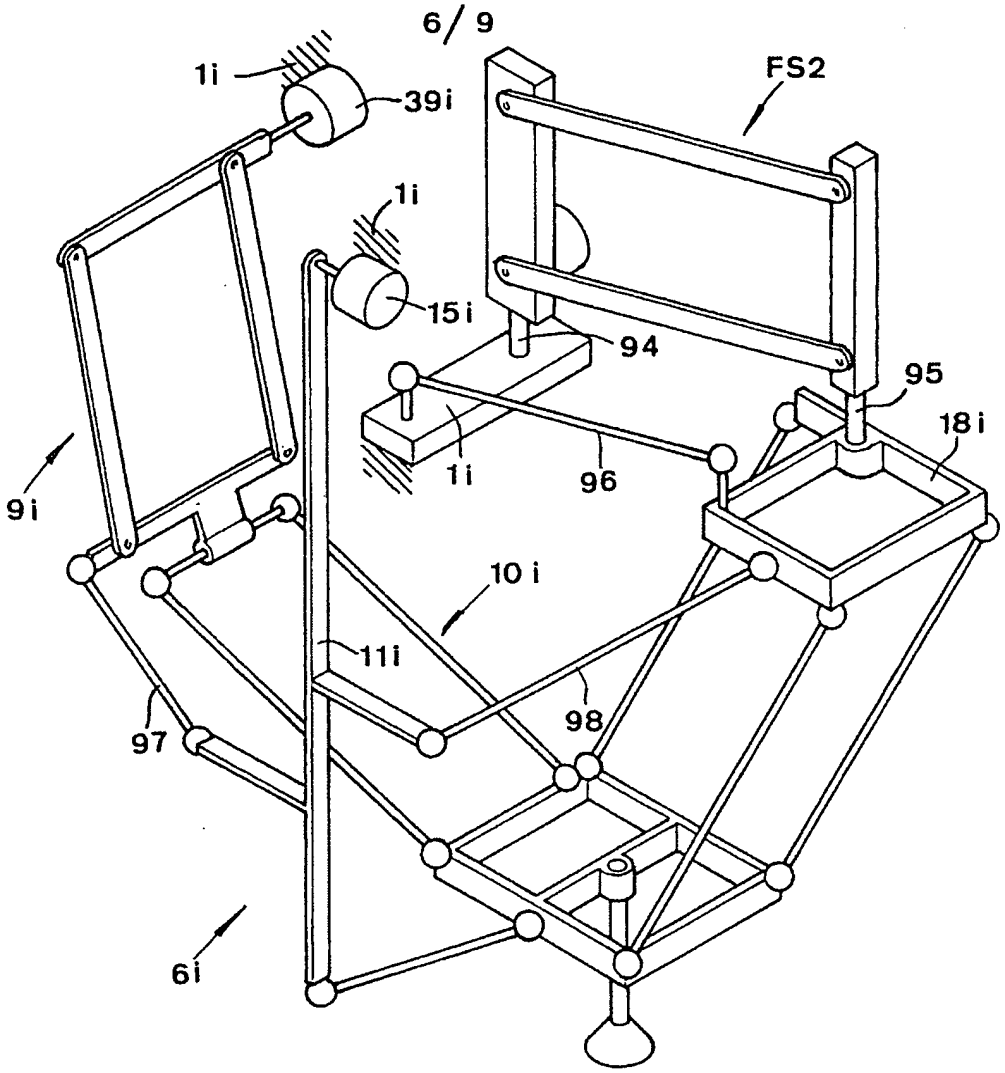

Fig 11

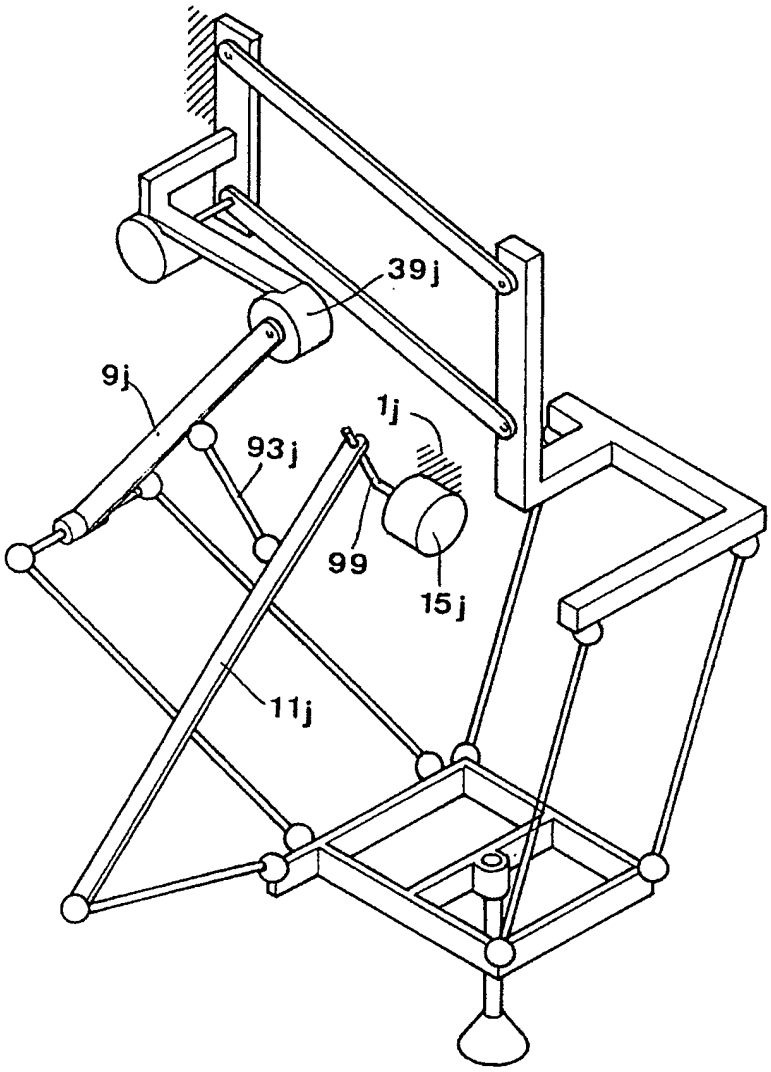

Fig 12

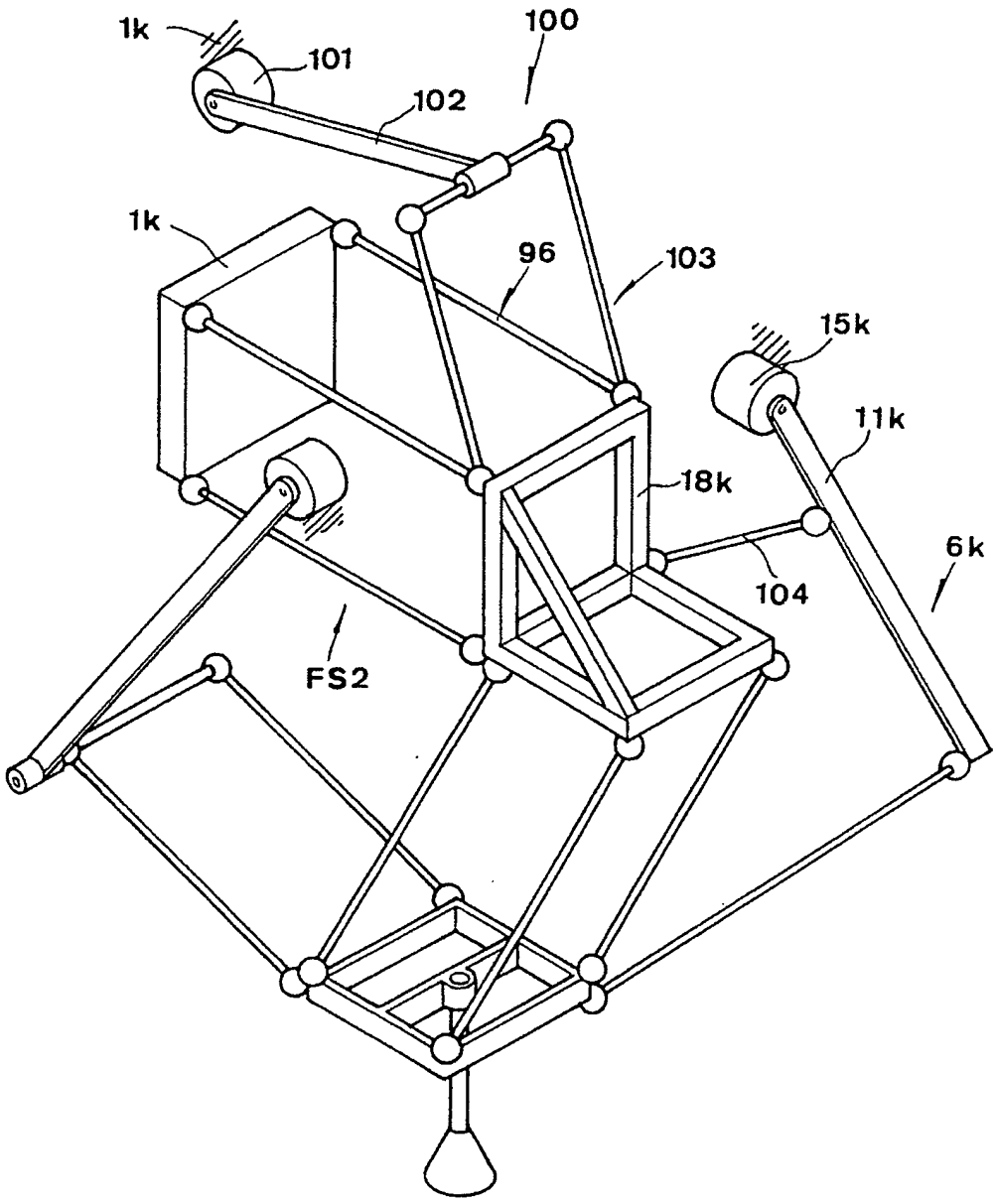

Fig 13

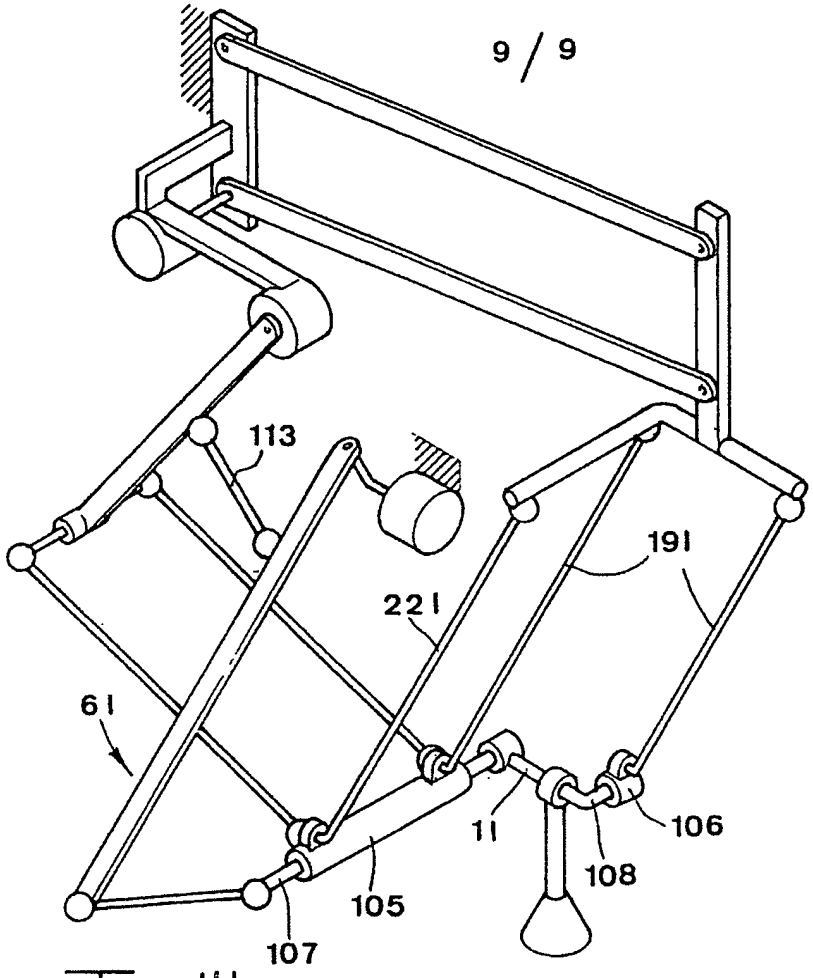
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Fig 14

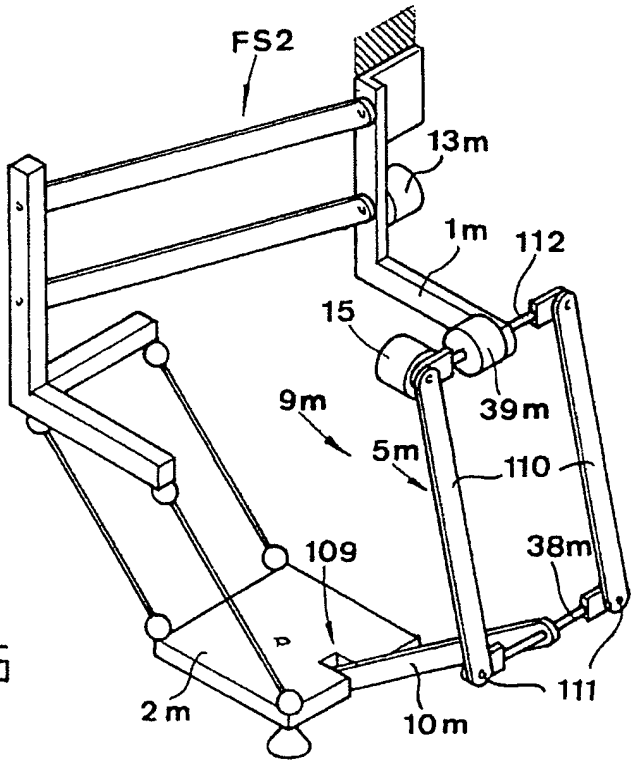
FS2
13m
1m
112
15
39m
9m
5m
110
109
38m
111
2m
10m

Fig 15

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/01626

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: B25J 9/10, B25J 11/00, B25J 17/02
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: B25J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0127895 A2 (SUMITOMO ELECTRIC INDUSTRIES LIMITED), 12 December 1984 (12.12.84), figures 2,4, claims 1,2	1,25,26,32
Y		2-14,27-31, 33,35,36
	--	
X	US 5156062 A (W.T. APPLEBERRY), 20 October 1992 (20.10.92), figures 1-3, abstract	1,25,26
Y		2-14,33,35
	--	
X	US 5237887 A (W.T. APPLEBERRY), 24 August 1993 (24.08.93), figures 1,3,6,7, abstract	1,25,26
	--	

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 December 1998	16 -12- 1998
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Mariana Eddin Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/01626

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 9511780 A1 (HAYWARD, V.), 4 May 1995 (04.05.95), figure 1, abstract	1
Y	US 5219266 A (C. REBOULET ET AL), 15 June 1993 (15.06.93), column 3, line 8 - line 13; column 3, line 51 - line 65, figures 1-3	36
Y	US 4976582 A (R. CLAVEL), 11 December 1990 (11.12.90), figure 3, abstract	36
Y	SE 502256 C2 (N. KLINTBERG), 25 Sept 1995 (25.09.95), figure 3, abstract	27-31
P,Y	WO 9733726 A1 (ASEA BROWN BOVERI AB), 18 Sept 1997 (18.09.97)	2-14,33,35

INTERNATIONAL SEARCH REPORT

Information on patent family members

03/11/98

International application No.
PCT/SE 98/01626

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